UASLP–IF–03–008

Review of Recent Results in Charm Physics[1]

Jürgen Engelfried

Instituto de Física, Universidad Autónoma de San Luis Potosí, San Luis Potosí 78000, México
jurgen@ifisica.uaslp.mx

Abstract. A biased review of recent results in charm physics is presented. New results on $D^0 - \overline{D^0}$ mixing, rare decays of D^0 and $D^{\pm}$, scalar resonances in D^+ and D_s decays, and new decay modes and mass measurements in Λ_c^+, $\Xi_c^{+,0}$, Ω_c^0, and Ξ_{cc}^+ are discussed.

INTRODUCTION

In contrary to the last 5 years or so, were mostly "traditional" charm experiments like E791, FOCUS, SELEX, WA89, WA92, CLEO, and H1/ZEUS published results about more "traditional" topics like production, lifetimes, rare decays, and limits on $D^0 - \overline{D^0}$ mixing, accompanied by a small number of theory and phenomenology papers, in the last year a shift in charm physics occurred. New players like BaBar, Belle and CDF entered the field, new charm states (doubly charmed baryons, hidden double charm ($J/\Psi c\bar{c}$), D_s^*, $X(3872)$) were discovered, and the first pentaquark was observed. All this triggered a large number of "theory" papers, pre- and post-dicting the spectroscopy and production of these new states. In most of these papers a (back-)shift to the di-quark picture of charmed hadrons can be observed.

We will present here a (biased) selection of recent results in charm physics. In several other talks at this conference charm results were shown.

$\mathbf{D^0 - \overline{D^0}}$ MIXING

The usual observable for *CP* violation in the charm system is the lifetime difference between $D^0 \to K^-K^+$ and $D^0 \to K^-\pi^+$, defined as $y_{CP} = \tau(K^-\pi^+)/\tau(K^-K^+) - 1$, predicted in the Standard Model to $y_{CP} \sim 10^{-3}$. Another possible analysis is the "wrong-sign" Double Cabbibo Suppressed $D^0 \to K^+\pi^-$, with the observable y'. Recent results where published by Belle [1] and BaBar [2], and are compared with previous results in table 1.

All measurements are compatible with 0, e.g. no *CP* violation was observed yet in the charm system.

RARE DECAYS OF $\mathbf{D^0}$ AND $\mathbf{D^{\pm}}$ MESONS

FOCUS observed the rare decay $D^0 \to K^-K^-K^+\pi^+$ with a yield of 132 ± 19 events, and measured the relative branching ratio to $\Gamma(D^0 \to K^-K^-K^+\pi^+)/\Gamma(D^0 \to K^-\pi^-\pi^+\pi^+) = 0.00257 \pm 0.00034 \pm 0.00024$ [8]. Resonant Resonant substructures with Φ and $\overline{K^*(892)^0}$ are dominant.

Belle observed $D^0 \to \phi\pi^0$, $\phi\eta$, and $\phi\gamma$ [9].

CLEO performed a Dalitz plot analysis of $D^0 \to \pi^-\pi^+\pi^0$, and studied $D^0 \to K_s\eta\pi^0$ [10]. CLEO also observed the Cabbibo suppressed decays $D^+ \to \pi^+\pi^0$, $K^+\overline{K^0}$, and $K^+\pi^0$ [11], and the measured Branching Ratios are shown in table 2.

FOCUS studied di-muon decays for D^+ and D_s^+ [12], and obtained new limits on these modes.

A new player in the field, CDF, set a limit for $D^0 \to \mu^+\mu^-$ at $< 2.5 \cdot 10^{-6}$ [13].

SCALAR RESONANCES IN $\mathbf{D^+}$ AND $\mathbf{D_s^+}$ DECAYS

Since a few years E791 is studying the modes $D^+ \to K^-\pi^+\pi^+$, $D^+ \to \pi^-\pi^+\pi^+$, and $D_s^+ \to \pi^-\pi^+\pi^+$. To explain the resonant substructures in the decays, they need to include two scalar resonance, one for $K\pi$ (the κ) with mass $(797 \pm 19 \pm 43)\,\mathrm{MeV}/c^2$ and width

[1] Invited talk the 9th International Conference on B-Physics at Hadron Machines – BEAUTY 2003, Carnegie Mellon University, Pittsburgh, October 14-18, 2003. Proceedings to be published by AIP.

TABLE 1. Recent measurements of CP violation observables in the D^0 system.

Experiment	Measurement	Reference
Belle	$y_{CP} = (+1.15 \pm 0.69 \pm 0.38)\,\%$	[1]
BaBar	$y_{CP} = (-0.8 \pm 0.4^{+0.5}_{-0.4})\,\%$	[2]*
CLEO	$y_{CP} = (-1.2 \pm 2.5 \pm 1.4)\,\%$	[3]†
FOCUS	$y_{CP} = (3.42 \pm 1.39 \pm 0.74)\,\%$	[4]
E791	$y_{CP} = (0.8 \pm 2.9 \pm 1.0)\,\%$	[5]**
BaBar	$-0.056 < y' < 0.039$ (95% C.L.)	[6]
CLEO	$-0.058 < y' < 0.01$ (95% C.L.)	[7]

* also includes $D^0 \to \pi^+\pi^-$
† also includes $D^0 \to \pi^+\pi^-$
** Measured $\Delta\Gamma = (0.04 \pm 0.14 \pm 0.05)\,\mathrm{ps}^{-1}$

TABLE 2. Branching Ratios for D^+ decays, measured by CLEO [11].

$\mathscr{B}(D^+ \to \pi^+\pi^0)$	$(1.31 \pm 0.17 \pm 0.09 \pm 0.09) \cdot 10^{-3}$
$\mathscr{B}(D^+ \to K^+\overline{K^0})$	$(5.24 \pm 0.43 \pm 0.20 \pm 0.34) \cdot 10^{-3}$
$\mathscr{B}(D^+ \to K^+\pi^0)$	$< 4.2 \cdot 10^{-4}$ (90% C.L.)

TABLE 3. Masses and Width for Σ_c^{++} and Σ_c^0 as measured by CLEO [24].

$M(\Sigma_c^{++}) - M(\Lambda_c^+)$	$(167.4 \pm 0.1 \pm 0.2)\,\mathrm{MeV}/c^2$
$M(\Sigma_c^{0}) - M(\Lambda_c^+)$	$(167.2 \pm 0.1 \pm 0.2)\,\mathrm{MeV}/c^2$
$\Gamma(\Sigma_c^{++})$	$(2.3 \pm 0.2 \pm 0.3)\,\mathrm{MeV}/c^2$
$\Gamma(\Sigma_c^{0})$	$(2.5 \pm 0.2 \pm 0.3)\,\mathrm{MeV}/c^2$

$(410 \pm 43 \pm 87)\,\mathrm{MeV}/c^2$, and a second in $\pi\pi$ (the σ) with mass $(478^{+24}_{-23} \pm 17)\,\mathrm{MeV}/c^2$ and width $(324^{+42}_{-40} \pm 21)\,\mathrm{MeV}/c^2$ [14, 15, 16].

THE $\mathbf{D_s}$ SYSTEM

On April 12, 2003, BaBar announced the observation of a narrow resonance, decaying to $D_s\pi^0$, at $2.32\,\mathrm{GeV}/c^2$ [17]. Shortly after, CLEO not only confirmed the observation, but observed an additional resonance, decaying to $D_s^*\pi^0$ [18, 19]. During the summer conferences, Belle confirmed both observations [20, 21]. The most likely nature of these states are excited D_s mesons; the search for similar states in the D^0 and $D^\pm$ system already started. More details can be found in these proceedings [22].

CHARMED BARYONS: THE Λ_c^+ AND $\Sigma_c^{0,++}$

CLEO reports the observation of the $\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-\pi^0$ decay [23], with $\mathscr{B} = (1.79 \pm 0.47 \pm 0.43)\,\%$, while most of the decays happen via $\Lambda_c^+ \to \Lambda\omega\pi^+$.

CLEO also measured the masses and widths of Σ_c^{++} and Σ_c^0 [24] (the results are shown in table 3), updating previous results on the masses from E791 [25].

CHARMED BARYONS: THE Ξ_c^+ AND Ξ_c^0

FOCUS measured several new decay modes of the Ξ_c^+ and re-measured some previously observed ones. A summary is given in table 4. FOCUS also includs upper limits for resonances in these decay modes.

CLEO obtained a new measurement of the Ξ_c^+ lifetime, $\tau(\Xi_c^+) = (503 \pm 47 \pm 18)\,\mathrm{fs}$ [29].

CLEO also reports the first observation of the $\Xi_c^0 \to pK^-K^-\pi^+$ decay [30], with a relative branching ratio of $\mathscr{B}(\Xi_c^0 \to pK^-K^-\pi^+)/\mathscr{B}(\Xi_c^0 \to \Xi^-\pi^+) = 0.35 \pm 0.08 \pm 0.05$. In this decay they see evidence for a resonant $\overline{K^*(892)^0}$ substructure.

CHARMED BARYONS: THE Ω_c^0

Evidence for the Ω_c^0 in e^+e^- interactions was reported long time ago by ARGUS [31], and now first CLEO [32] and recently Belle [33, 34] confirm this observation. Both measure the mass of the Ω_c^0 (Belle: $(2693.9 \pm 1.1 \pm 1.4)\,\mathrm{MeV}/c^2$, CLEO: $(2694.6 \pm 2.6 \pm 1.9)\,\mathrm{MeV}/c^2$) significantly different from the PDG2000: $(2704 \pm 4)\,\mathrm{MeV}/c^2$ [35]. Both observe the mode $\Omega_c^0 \to \Omega^-\pi^+$ and $\Omega_c^0 \to \Omega^-e^+\nu$, and Belle observes in addition the semileptonic muon mode.

TABLE 4. Relative Branching Ratios for Ξ_c^+.

Decay Mode	FOCUS [26]	CLEO[27]	SELEX [28]
$\frac{\Gamma(\Xi_c^+\to\Sigma^+K^-\pi^+)}{\Gamma(\Xi_c^+\to\Xi^-\pi^+\pi^+)}$	$0.91\pm0.11\pm0.04$	$1.18\pm0.26\pm0.17$	$0.92\pm0.20\pm0.07$
$\frac{\Gamma(\Xi_c^+\to\Sigma^+K^+K^-)}{\Gamma(\Xi_c^+\to\Sigma^+K^-\pi^+)}$	$0.16\pm0.06\pm0.01$		
$\frac{\Gamma(\Xi_c^+\to\Lambda^0K^-\pi^+\pi^+)}{\Gamma(\Xi_c^+\to\Xi^-\pi^+\pi+)}$	$0.28\pm0.06\pm0.06$	$0.58\pm0.16\pm0.07$	
$\frac{\Gamma(\Xi_c^+\to\Omega^-K^+\pi^+)}{\Gamma(\Xi_c^+\to\Xi^-\pi^+\pi+)}$	$0.07\pm0.03\pm0.03$		
$\frac{\Gamma(\Xi_c^+\to\Sigma^*(1385)^+\overline{K^0})}{\Gamma(\Xi_c^+\to\Xi^-\pi^+\pi+)}$	$1.00\pm0.49\pm0.24$		

DOUBLY CHARMED BARYONS: THE Ξ_{cc}^+

The SELEX experiment reported the first observation of a member of the doubly charmed baryon family, the Ξ_{cc}^+, in the decay mode $\Xi_{cc}^+\to\Lambda_c^+K^-\pi^+$ [36]. Further work on different decay modes is ongoing.

ACKNOWLEDGMENTS

I would like to thank John Cumalat and Erik Gottschalk from FOCUS, Sheldon Stone and JC Wang from CLEO, Jeff Appel from E791, Masa Yamauchi and Karim Trabelsi from Belle, and Livio Lanceri from BaBar for providing me with information and figures from their respective experiments.

I would also like to thank the organizers of the conference for the opportunity to give this presentation.

REFERENCES

1. Abe, K., et al., *hep-ex/0308034* (2003).
2. Aubert, B., et al., *Phys. Rev. Lett.*, **91**, 121801 (2003).
3. Csorna, S. E., et al., *Phys. Rev.*, **D65**, 092001 (2002).
4. Link, J. M., et al., *Phys. Lett.*, **B485**, 62–70 (2000).
5. Aitala, E. M., et al., *Phys. Rev. Lett.*, **83**, 32 (1999).
6. Aubert, B., et al., *Phys. Rev. Lett.*, **91**, 171801 (2003).
7. Godang, R., et al., *Phys. Rev. Lett.*, **84**, 5038–5042 (2000).
8. Link, J. M., et al., *Phys. Lett.*, **B575**, 190–197 (2003).
9. Abe, K., et al., *hep-ex/0308037* (2003).
10. Dubrovin, M. S., *hep-ex/0305006* (2003).
11. Arms, K., et al., *hep-ex/0309065* (2003).
12. Link, J. M., et al., *Phys. Lett.*, **B572**, 21–31 (2003).
13. Acosta, D., et al., *Phys. Rev.*, **D68**, 091101 (2003).
14. Aitala, E. M., et al., *Phys. Rev. Lett.*, **89**, 121801 (2002).
15. Aitala, E. M., et al., *Phys. Rev. Lett.*, **86**, 770–774 (2001).
16. Bediaga, I., *hep-ex/0307008* (2003).
17. Aubert, B., et al., *Phys. Rev. Lett.*, **90**, 242001 (2003).
18. Besson, D., et al., *Phys. Rev.*, **D68**, 032002 (2003).
19. Stone, S., and Urheim, J., *AIP Conf. Proc.*, **687**, 96–104 (2003).
20. Krokovny, P., et al., *hep-ex/0308019* (2003).
21. Abe, K., et al., *hep-ex/0307052* (2003).
22. Wang, J., *these proceedings* (2003).
23. Cronin-Hennessy, D., et al., *Phys. Rev.*, **D67**, 012001 (2003).
24. Artuso, M., et al., *Phys. Rev.*, **D65**, 071101 (2002).
25. Aitala, E. M., et al., *Phys. Lett.*, **B379**, 292–298 (1996).
26. Link, J. M., et al., *Phys. Lett.*, **B571**, 139–147 (2003).
27. Bergfeld, T., et al., *Phys. Lett.*, **B365**, 431–436 (1996).
28. Jun, S. Y., et al., *Phys. Rev. Lett.*, **84**, 1857–1861 (2000).
29. Mahmood, A. H., et al., *Phys. Rev.*, **D65**, 031102 (2002).
30. Danko, I., et al. (2003).
31. Albrecht, H., et al., *Phys. Lett.*, **B288**, 367–372 (1992).
32. Cronin-Hennessy, D., et al., *Phys. Rev. Lett.*, **86**, 3730–3734 (2001).
33. Ammar, R., et al., *Phys. Rev. Lett.*, **89**, 171803 (2002).
34. Abe, K., et al., *Lepton-Photon 2003, BELLE-CONF-0333* (2003).
35. Groom, D. E., et al., *Eur. Phys. J.*, **C15**, 1–878 (2000).
36. Mattson, M., et al., *Phys. Rev. Lett.*, **89**, 112001 (2002).